

Igor Pogorelsky

Accelerator Test Facility status and near-term plans



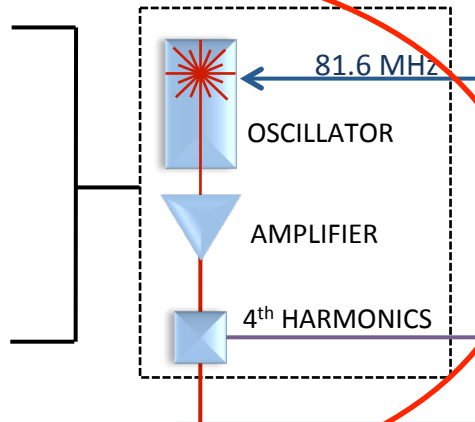
Outline

- *Introduction : ATF unique capabilities*
- *What's new since 16th User meeting?*
 - *Administrative changes*
 - *Sampling of user accomplishments*
 - *Survey of active, finished and proposed experiments*
 - *Ongoing upgrades*
 - *ATF II*
- *Conclusion – Introduction to ATF II Upgrade Workshop*

Provides users with unique combination of high brightness electron- and laser- beams

Nd:YAG Laser

- $\lambda_1 = 1.06 \mu\text{m}$
 $\lambda_2 = 0.266 \mu\text{m}$
- 14-ps pulse
- Stability 1 ps



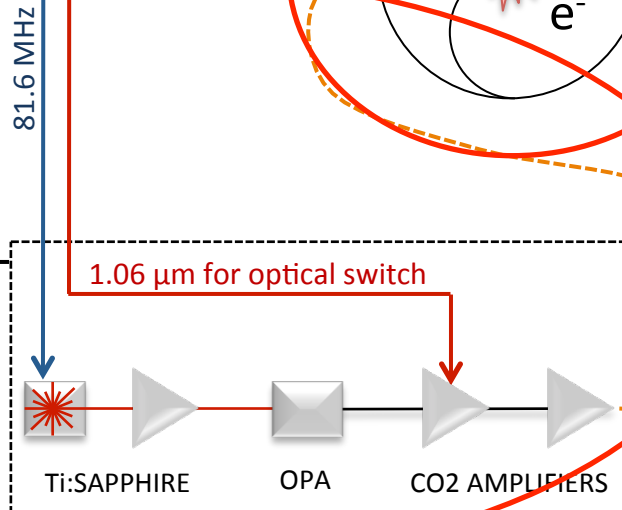
×35

RF Gun

1.6 cell S-band photocathode

Mid-IR (CO₂) Laser

- $\lambda = 9.2 - 10.6 \mu\text{m}$
- Single 3-ps pulse
- 2 TW peak power
- $a_0 = 1.4$
- 1 pulse in 20 sec



$h\nu$

e^-

80 MeV

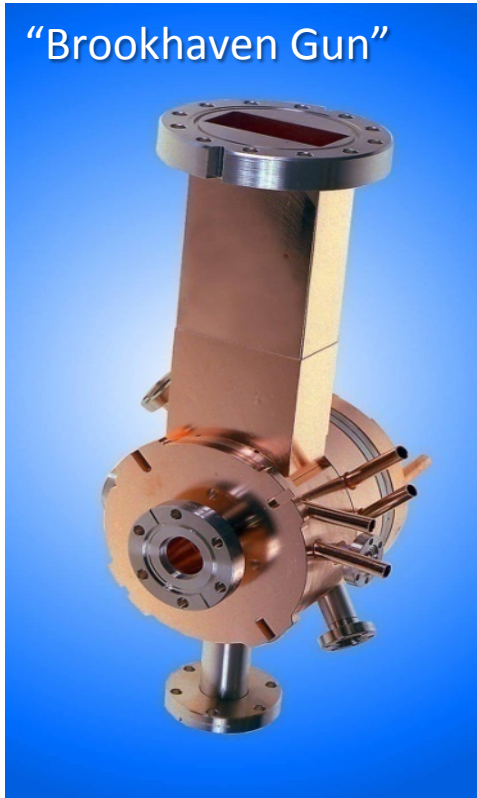
Linac

Two traveling wave SLAC sections

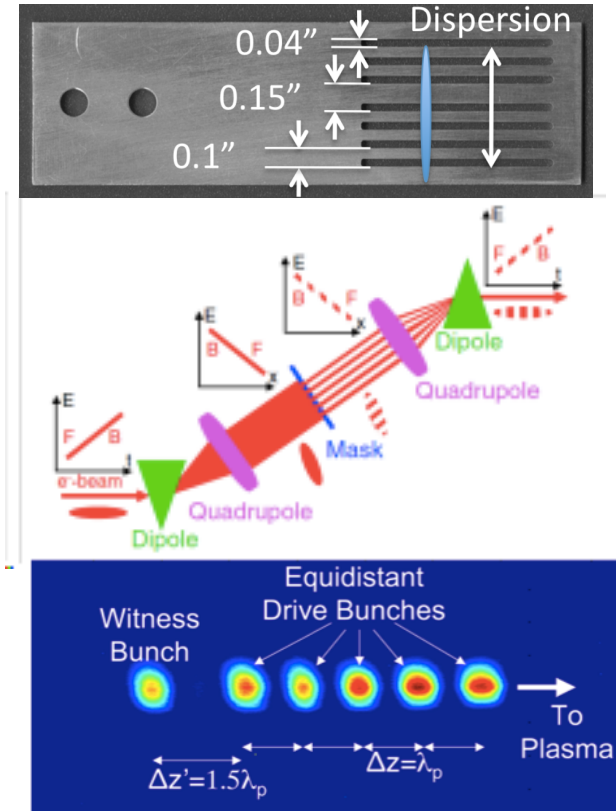
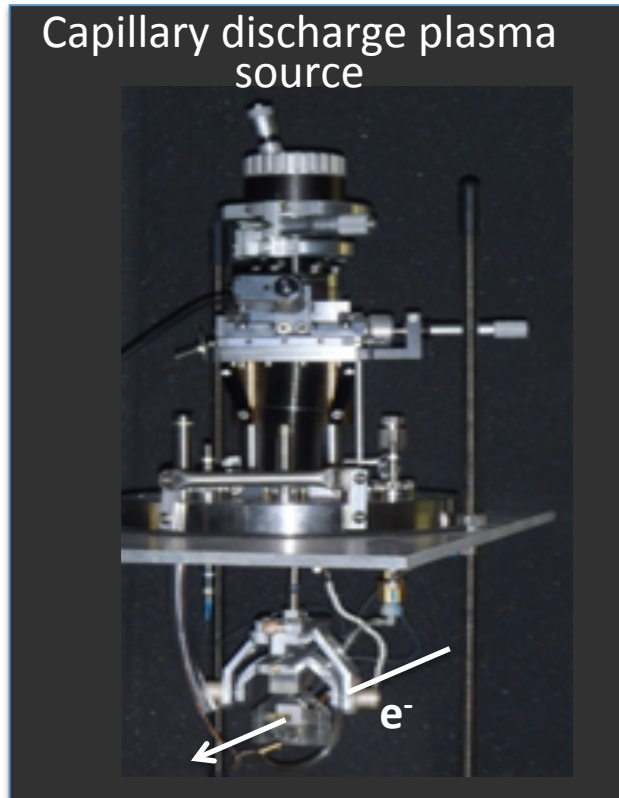
- Beam energy 30-80 MeV
- Bunch charge up to 1nC
- Normalized emittance 1.4 (best 0.8) mm mrad
- Bunch length 200 fs-10 ps

E-beam instrumentation

"Brookhaven Gun"

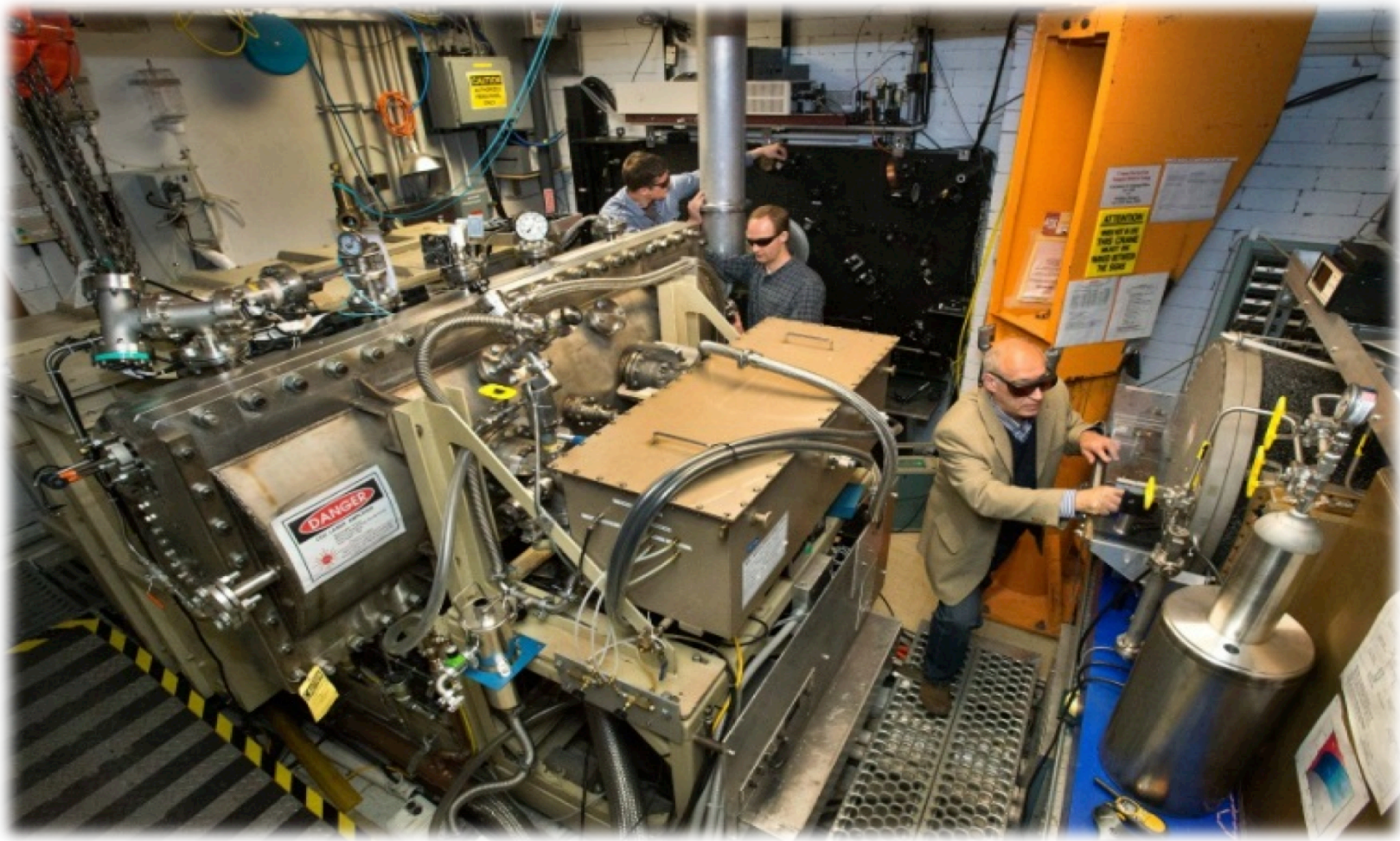


Capillary discharge plasma source



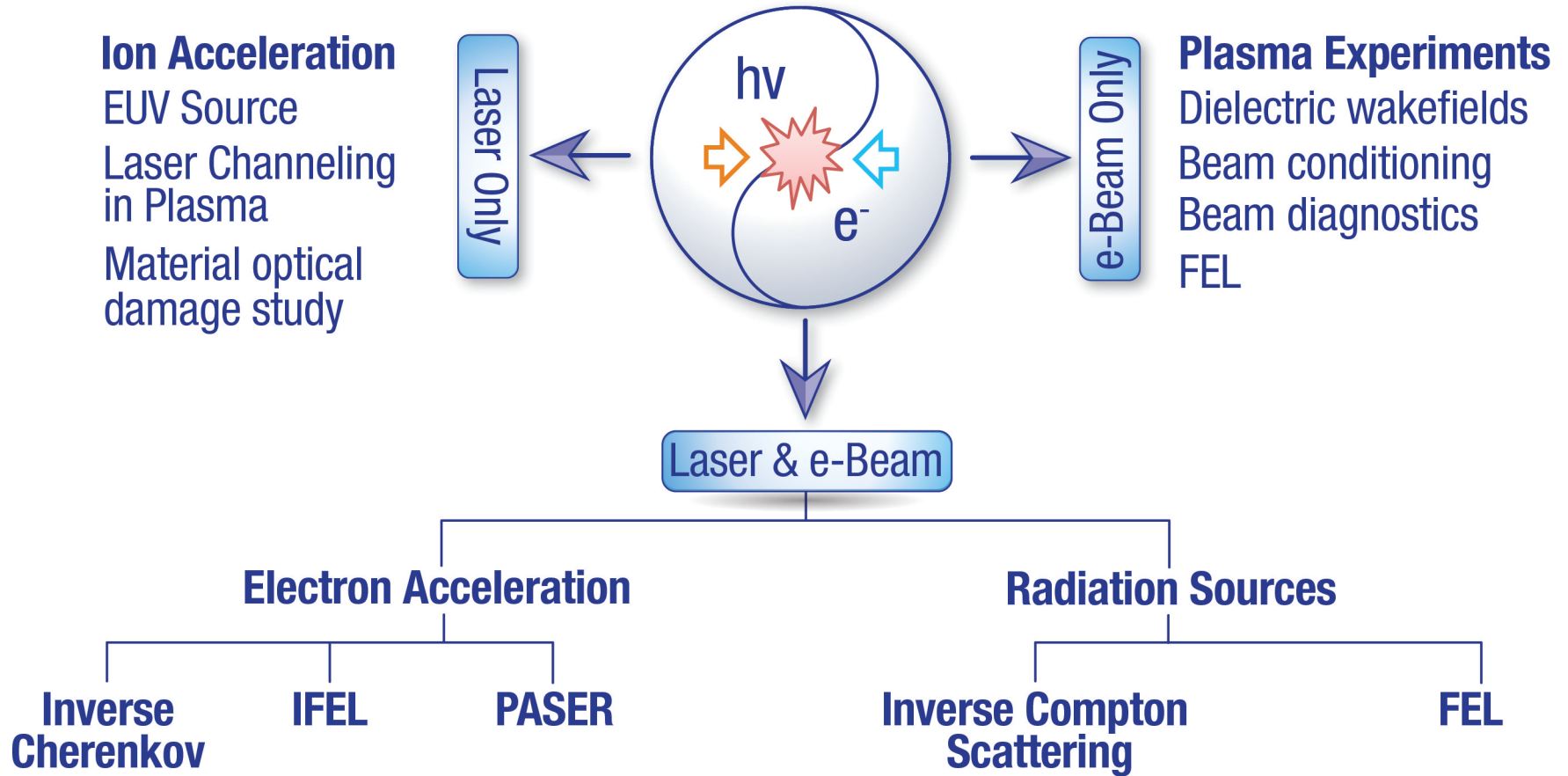
Mask technique

Unique IR lasers





Diversity in addressing needs of the accelerator community





ATF timeline since 16th User Meeting

- **April 2012**

16th ATF User Meeting.

New Scientific Program Director.

- September 2012

New ATF Director.

- April 2013

ATF move from Physics Dept. to C-AD.

- May 2013

DOE's call for the ATF Upgrade Proposal.

- July 2013

APAC in special meeting made recommendations on ATF upgrade.

- October 2013

Laser Advisory Panel made recommendations on 100TW laser upgrade.

- October 2013

ATF Upgrade Proposal presented to DOE.

- February 2014

DOE decision to fund the Stage I upgrade.

- March 2014

ATF recognized as the flagship user facility on Accelerator Stewardship.

- June 2014

BNL funds Program Development project on the CO₂ laser upgrade.

- July 2014

DOE funds available in the BNL financial plan. Facility's 3-year upgrade starts.

- **October 2014**

17th ATF User Meeting.



Science advancements since 16th User meeting

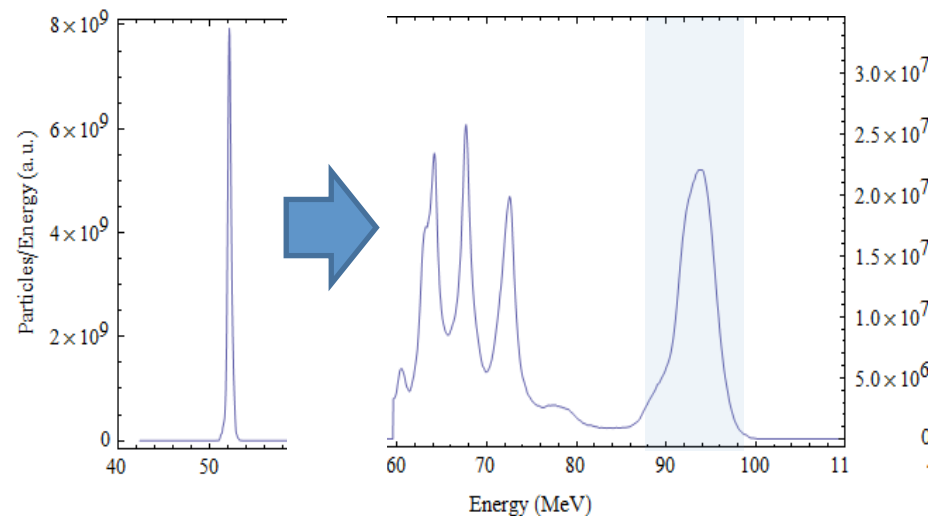
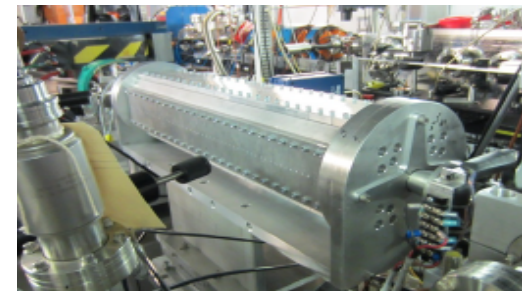
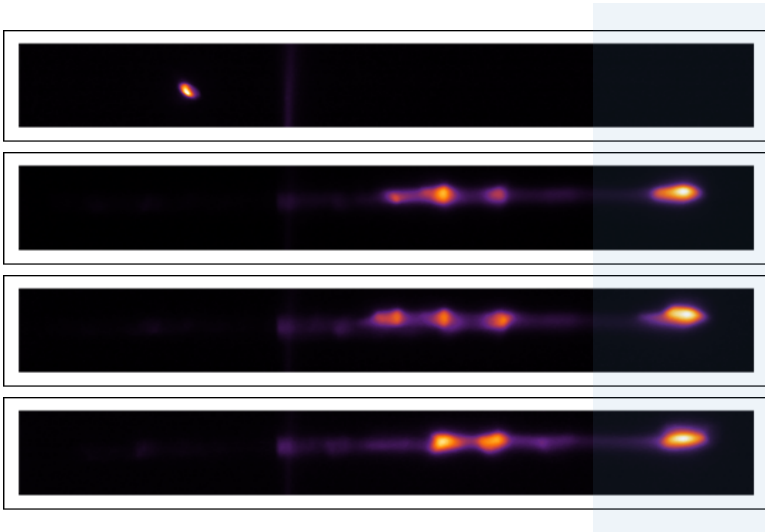
- First demonstration of mass-shift effect and multiple harmonics in inverse Compton scattering.
- Record-high acceleration gradient (100 MeV/m) and energy gain (50 MeV) from inverse FEL electron accelerator.
- Demonstration of energy chirp compensation in the electron beam by Wake Fields.
- Demonstration and study of a Plasma Wake Field in the Quasi-Nonlinear regime.
- Detailed study of a Shock Wave ion acceleration regime using two laser pulses impinging on a supersonic gas jet.
- Demonstration of 10% wall-plug efficiency in producing trains of picosecond pulses inside the CO₂ laser amplifier cavity aimed towards building a high-power Compton radiation source.
- Developing and partial verification of a novel ultra-fast CO₂ laser concept. With this laser the ATF contribution to the cutting-edge advanced accelerator research will change dramatically.

RUBICON - IFEL accelerator

(CO₂ and e-beam co-propagation in helical tapered undulator)



Up to 50 MeV (100 MeV/m) to compare
with previous IFEL record of 15 MeV

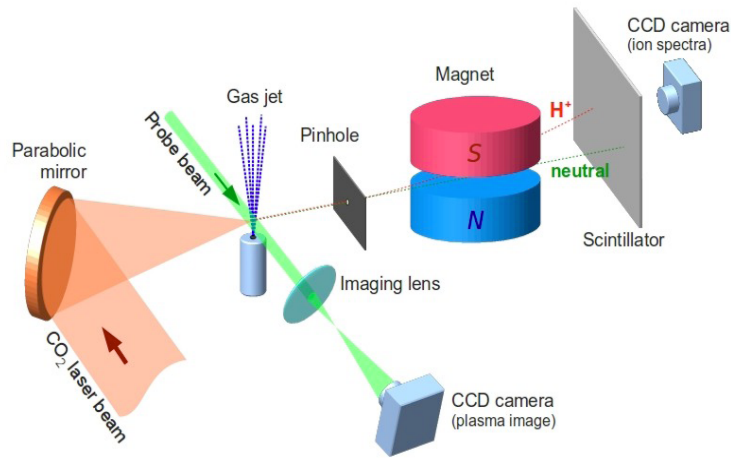


25 % capture @ >90 MeV
93.7 MeV mean, 2.0 % energy spread

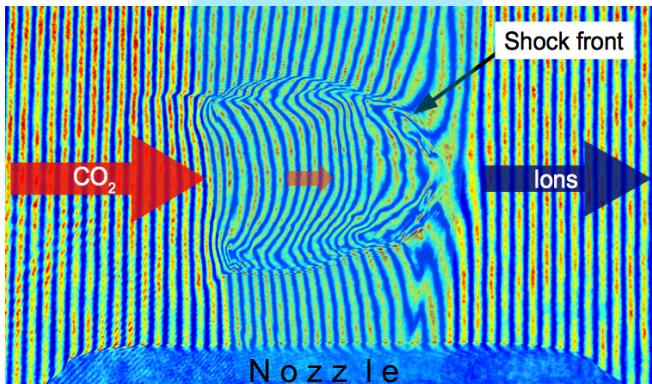
Shock Wave Proton Acceleration

Imperial College
London

STONY
BROOK



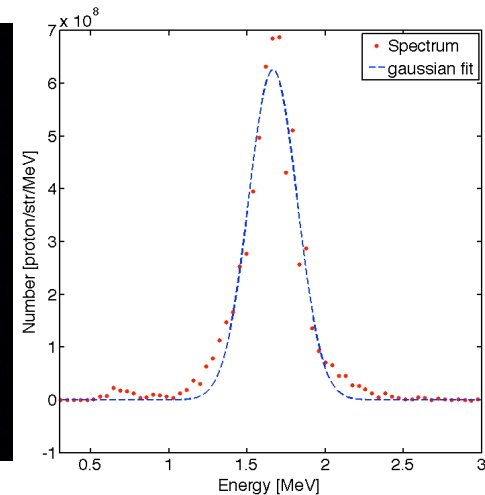
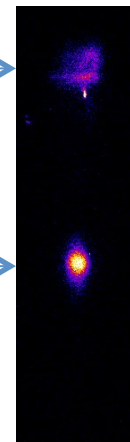
Hydrogen jet



Laser-induced electrostatic shock reflects protons upon its propagation through the ionized H_2 jet.

(light or
neutrals)

1.7 MeV
protons

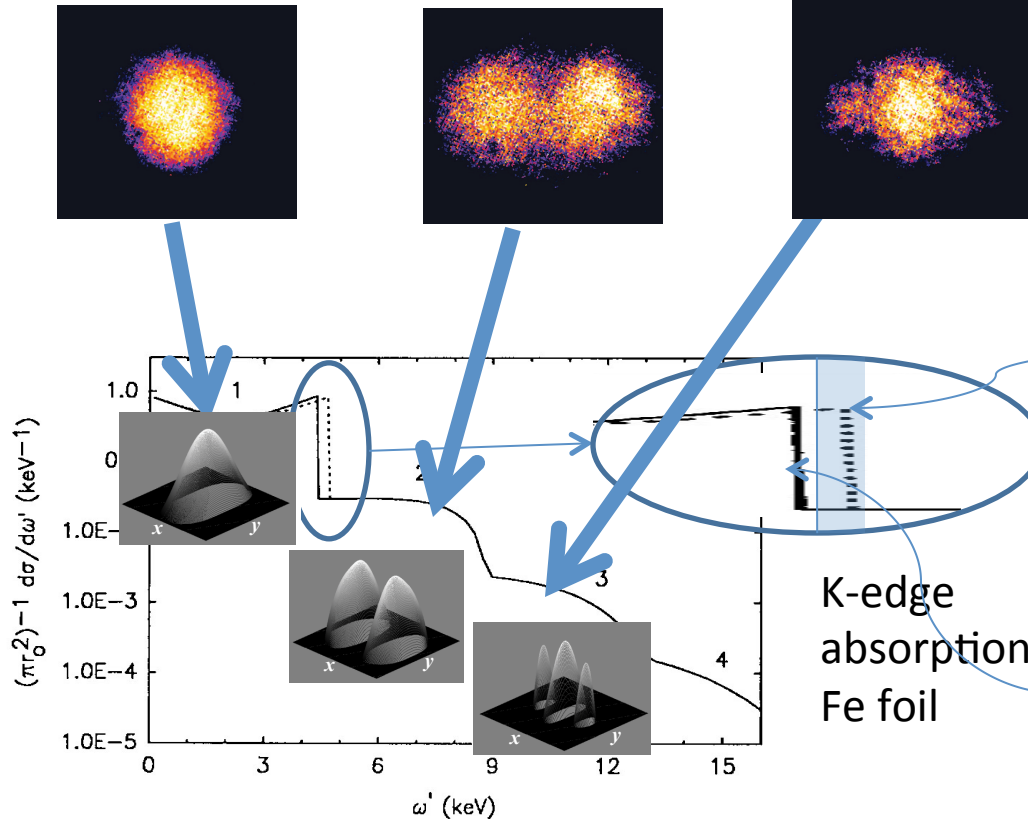


- Energy spread 10%
- Spectral brightness up to 10^9 proton/MeV/str
- Proton energy up to 3.2 MeV
- First observations of ~ 1 MeV He^+

Recent unpublished results in nonlinear Compton scattering



harmonics



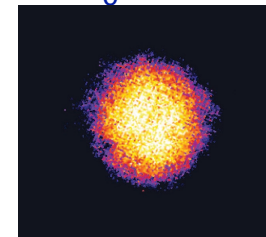
mass shift

$$\bar{m} = m \sqrt{1 + a_0^2}$$

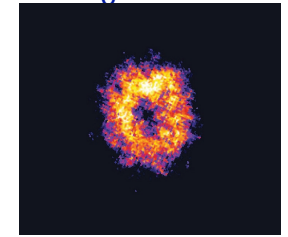
↓

$$\lambda_x \approx \frac{\lambda_L}{4\gamma^2} [1 + a_0^2]$$

High laser power
 $a_0 > 0.5$



Low laser power
 $a_0 < 0.1$



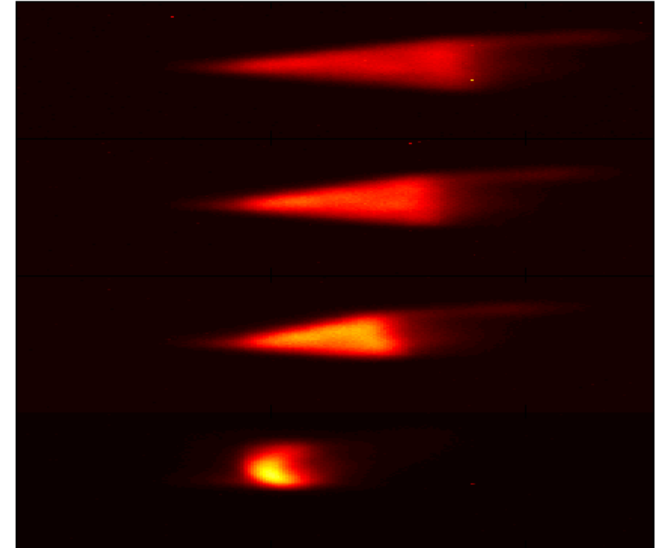
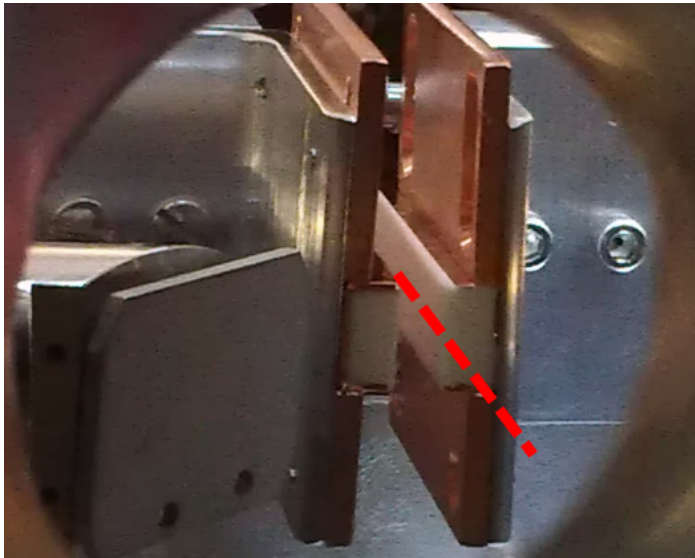
DWFA research

(acceleration, THz radiation, chirp correction)

PI – G. Andonian, UCLA

PI – S. Antipov, Euclid

Energy spread narrows as the gap changes

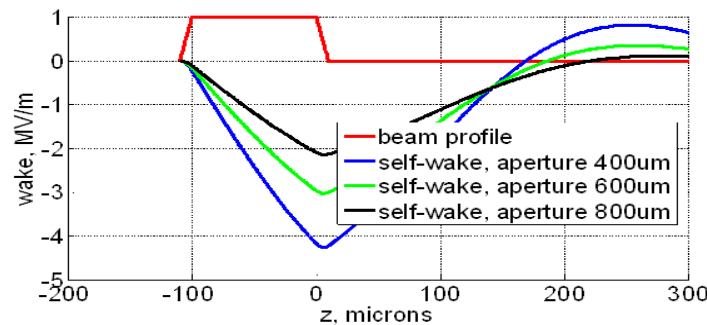


57

57.2

57.4

Energy, MeV





Active ATF Experiments

AE31 - Multi-bunch Plasma Wakefield Acceleration, Univ. Southern California (2004).

AE35 - High-brightness picosecond ion beam. SUNY SB (2005)

AE37- An X-band, traveling wave, deflection mode cavity. Radiabeam (2007)

AE39- DWA -high-gradient dielectric wakefield acceleration experiment. UCLA (2010)

AE41 - RUBICON - helical IFEL experiment at BNL. UCLA (2009)

AE43 - PWFA Holography. Un. Austin (2009)

AE45 - Advanced imaging and ultra-fast material probing with inverse Compton scattering. INFN (2009)

AE48 - Experimental study of electron-beam microbunching dynamics. Tel-Aviv U. (2010)

AE49 - Measurement of coherent terahertz radiation using a real-time interferometer. UCLA (2010)

AE50 - Plasma Wakefields in the Quasi-Nonlinear Regime. UCLA (2012)

- **FINISHED** - **Approved Between Meetings**

AE52 - Beam Manipulation by Self-Wakefield at the ATF. Euclid Technilabs (2012)

AF53 - Nonlinear inverse Compton scattering. UCLA(2012)

AF54 - AXIS -5-um damage test. Radiabeam/UCLA (2012)

AE56 - A High-resolution Transverse Diagnostic Based on Fiber Optics. Radiabeam (2013)

AF57 - Corrugated Plate De-Chirper. SLAC (2013)

AF58 - ERL BPM Test. BNL (C-AD) (2014)

AE59 Inverse Compton Source for Extreme Ultraviolet Lithography. Radiabeam (2013)

AE60 - Ultrafast High-Brightness Electron Source, Advanced Energy Systems (2012)

AE61 - Transient Noise of MCT Detector Array Due to 70 MeV Electrons. Jet Propulsion Lab. (2014)

AF62 - Sub-femtosecond beam line diagnostics. UCLA (2014)

AE63 - Stony Brook Accelerator Laboratory Course, CASE@ATF. Stony Brook Un (2014)

AF64 - Surface Wave Accelerator and Radiation Source Based on Silicon Carbide. U. Tex. Austin (2012)



17TH ATF USER AND APAC MEETING

Tuesday, October 14, 2014

8:30	9:00	APAC Executive Session
9:00	10:30	Opening and Facility Presentations
10:30	11:00	<i>Coffee break</i>
11:00	12:00	Experiment Status Reports
12:00	13:00	<i>Lunch break (working lunch for APAC)</i>
13:00	14:30	Experiment Status Reports
14:30	15:00	<i>Coffee break and Group Photo</i>
15:00	16:30	Experiment Status Reports
16:30	17:30	APAC Executive Session/ATF Tour #1
18:00		<i>User Meeting Dinner ("Sea Basin" restaurant, Rocky Point)</i>

Wednesday, October 15, 2014

8:30	9:00	APAC Executive Session
9:00	10:15	New Proposals
10:15	10:45	<i>Coffee break</i>
10:45	12:00	New Proposals
12:00	13:00	<i>Lunch break (working lunch for APAC)</i>
13:00	14:15	New Proposals
14:40	15:10	<i>Coffee break</i>
15:10	17:10	APAC Executive Session/ATF Tour #2
17:30	19:00	<i>Reception (bldg. 911, lobby)</i>



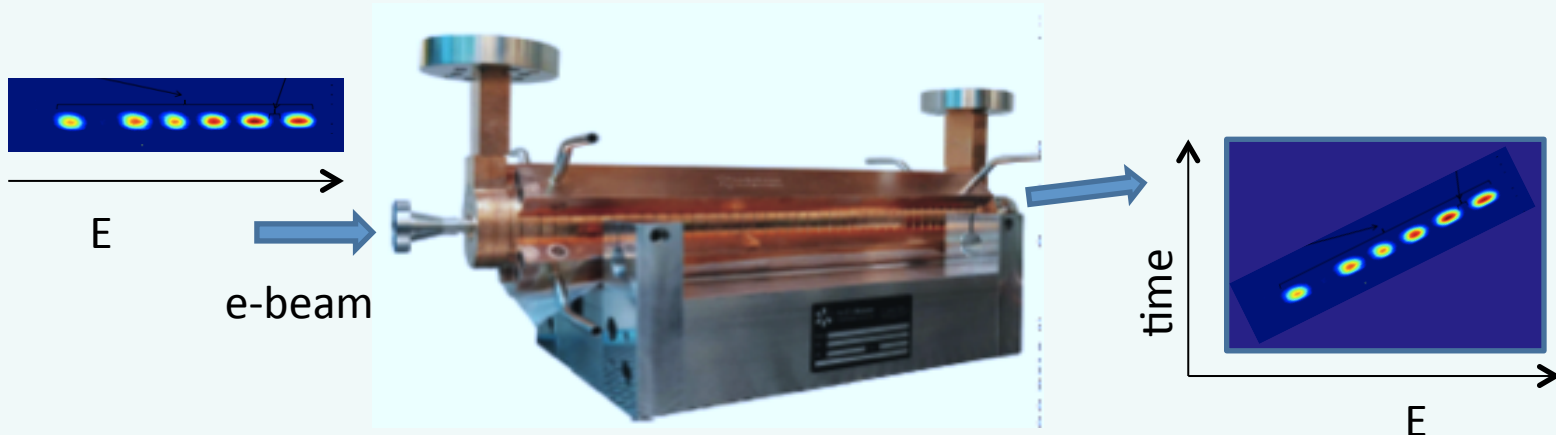
New Proposals

- P89** NOCIBUR: an inverse free electron laser decelerator experiment (UCLA)
- P90** Modification of Gas Jet Density Profile with Hydrodynamic Shocks for CO₂ Laser Ion Acceleration Experiment (NRL)
- P91** Space Radiation Effects Experiments (NASA)
- P92** Key physics study of laser wakefield acceleration utilizing ultrafast CO₂ laser and electron (Tsinghua Univ., China)
- P93** Ramped Beam Generation Using Dielectric Wakefield Structures (RadiaBeam)
- P94** Key physics study of LPI with NCD plasma using laser machined plasma structure (Tsinghua Univ., China)
- P95** Pre-bunched Dielectric Laser Acceleration with CO₂ Laser (LBNL, BNL)
- P96** CO₂-laser-driven GeV wakefield accelerators with external injection (SUNY SB, UCLA, Un. Texas in Austin, Tsinghua Univ.)
- P97** Nonlinear Inverse Compton Scattering (UCLA, Tokyo Un.)

Ongoing near-term facility upgrades

- E-Beam:
 - x-band deflection cavity
 - Half-year delay in putting a klystron to service due to accidental venting. Fully recovered.
 - Waveguide in manufacturing. Delivery and installation January 2015.

Deflection RF cavity will serve as ultra-fast streak-camera for e-beam



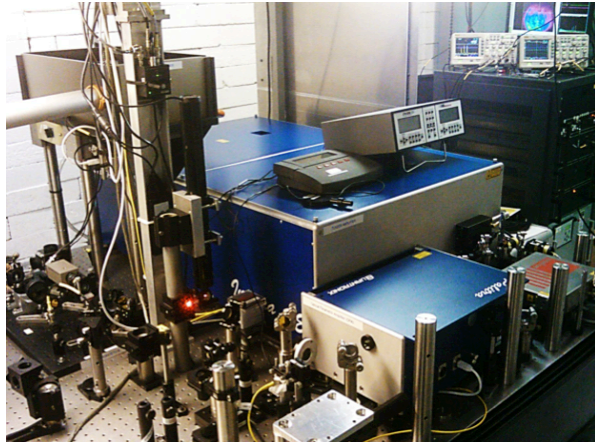


Ongoing near-term facility upgrades

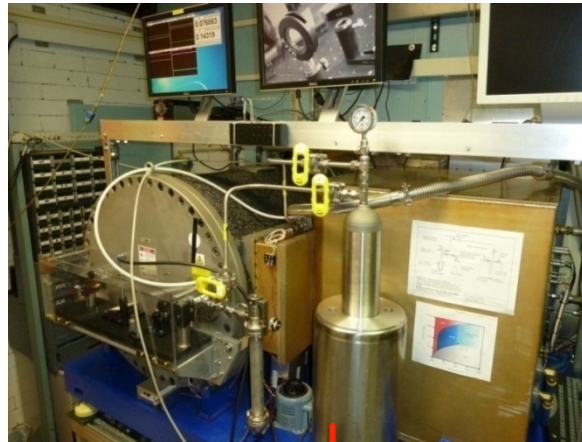
- CO₂ laser
 - Completed migration to solid-state OPA front end (up to 2TW)
 - CPA tests - in progress. Implementation early 2015 (~4TW)
 - Vacuum transport line - in manufacturing.
 - Next - R&D on nonlinear compression (~6-8TW)

Present-day CO₂ laser system

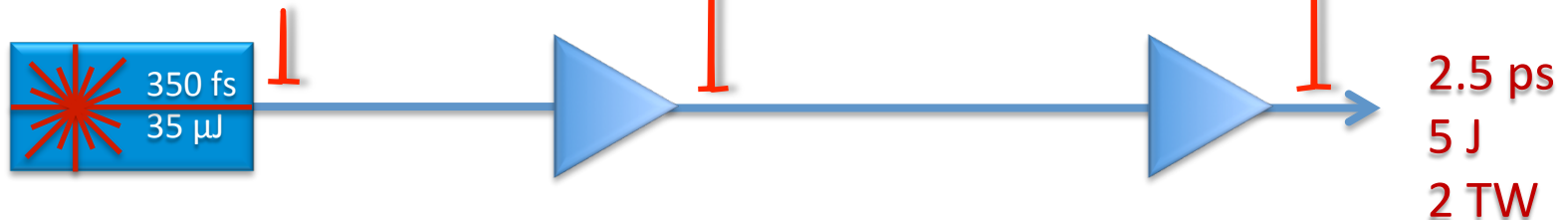
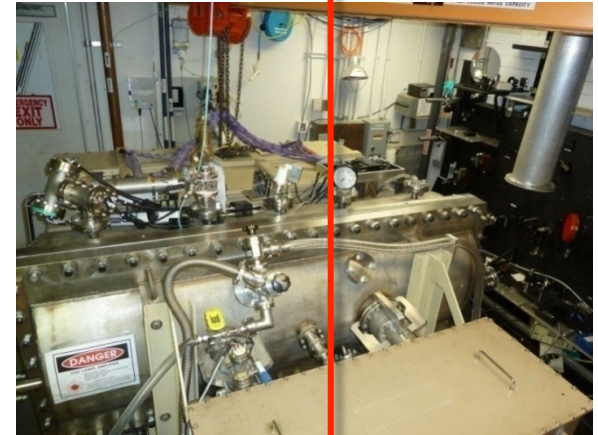
New SOLID-STATE
INJECTOR



REGEN



MAIN AMPLIFIER



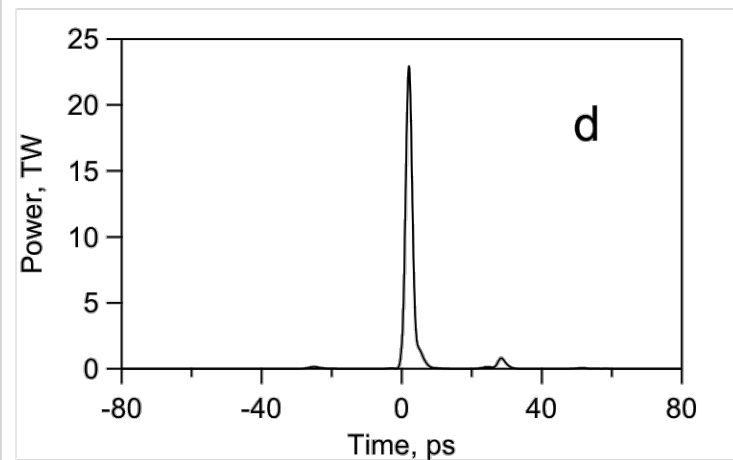
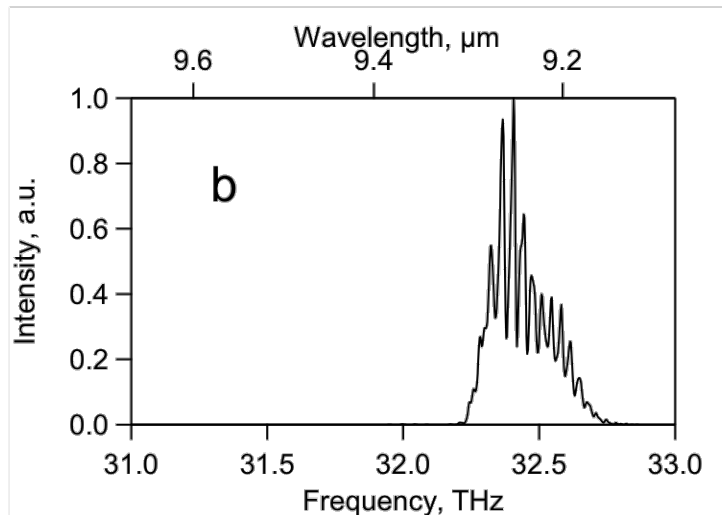
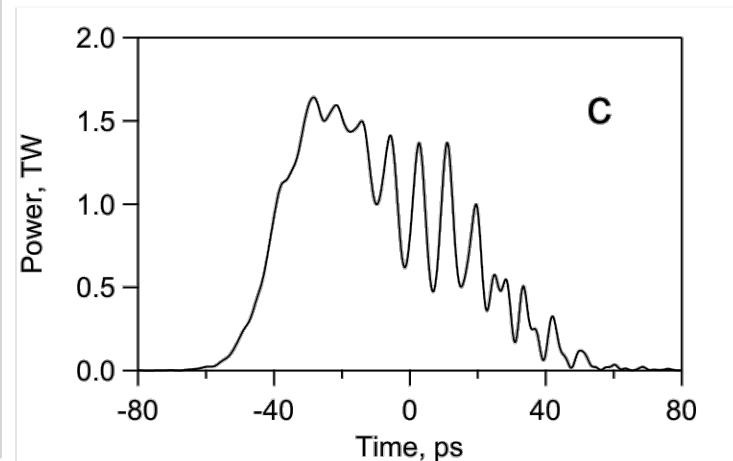
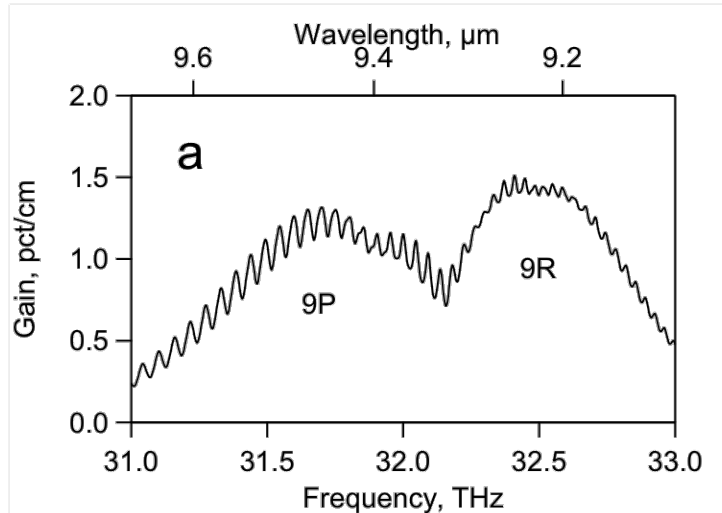
- User-friendly
- Shorter start-up, tune-up

- Shorter pulse
- Higher energy

- Higher repetition rate

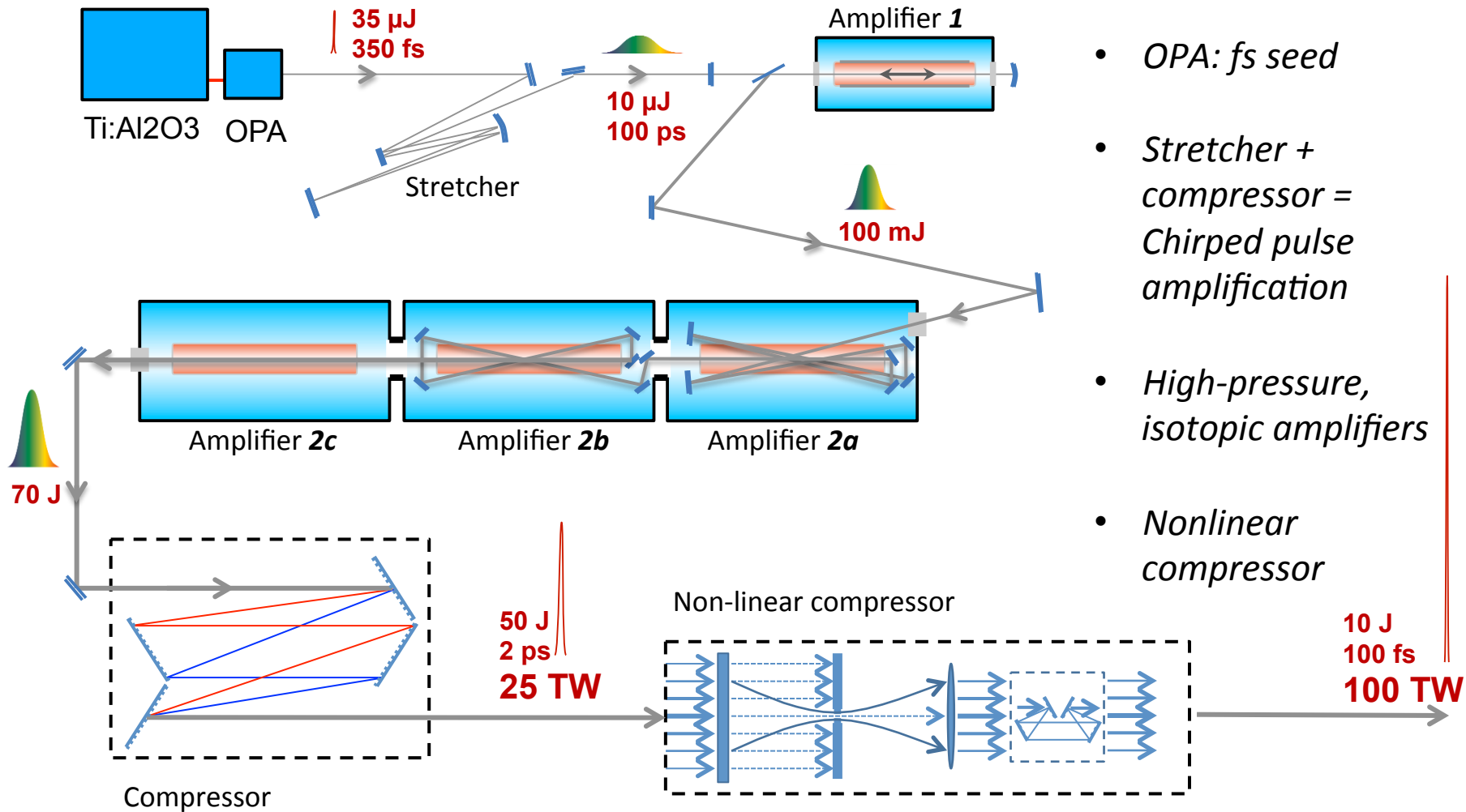


CPA simulations



tests are in progress

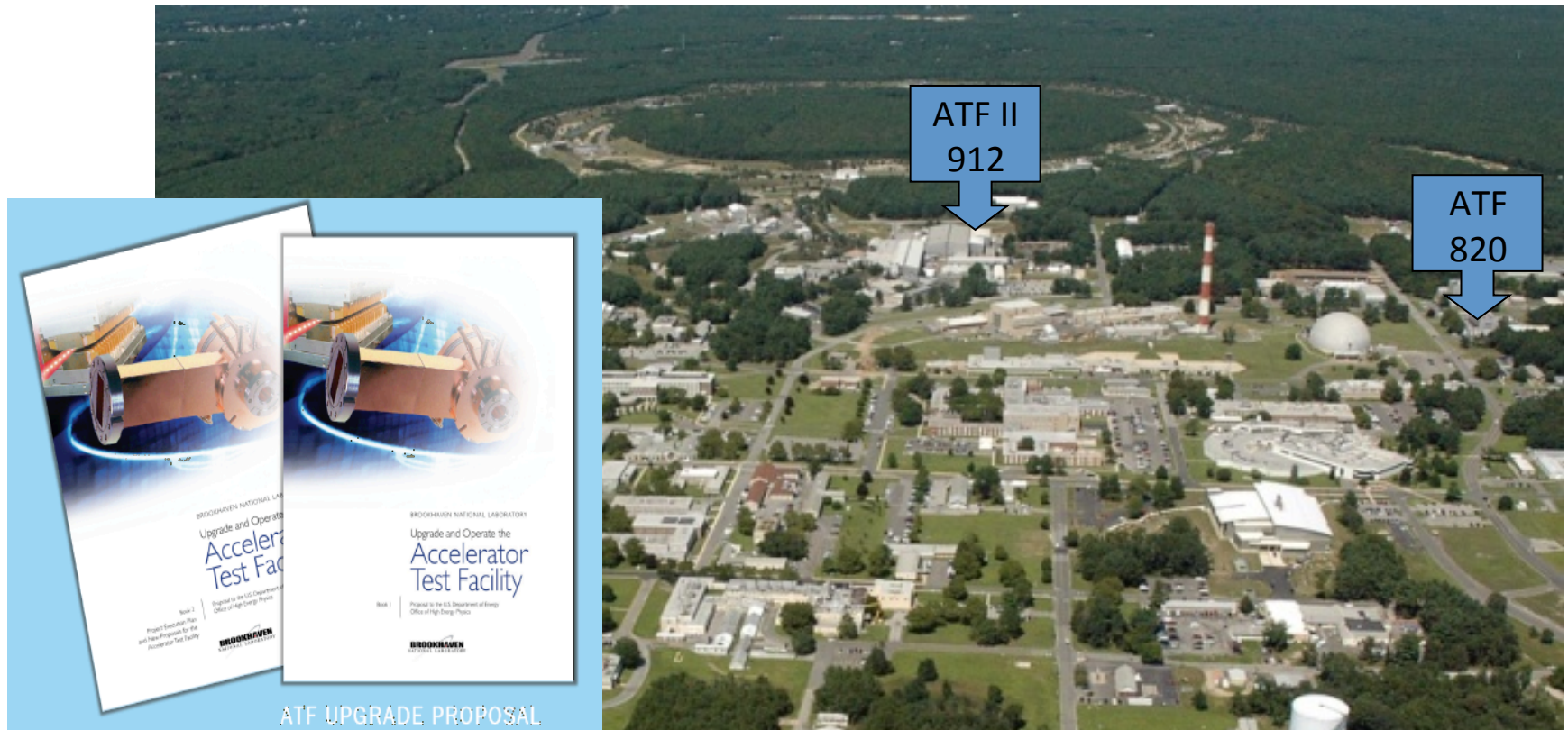
Principle diagram of 100 TW CO₂ laser



100-TW CO₂ laser

- Solid-state (QDP) seed-pulse generator
Done
2 TW 3 ps
- Chirped-pulse amplification
In tests
5-10 TW
- New (isotopic) RFQ main amplifier
RFQ sent
25 TW
- Nonlinear pulse compressor
R&D
100 TW 100 fs

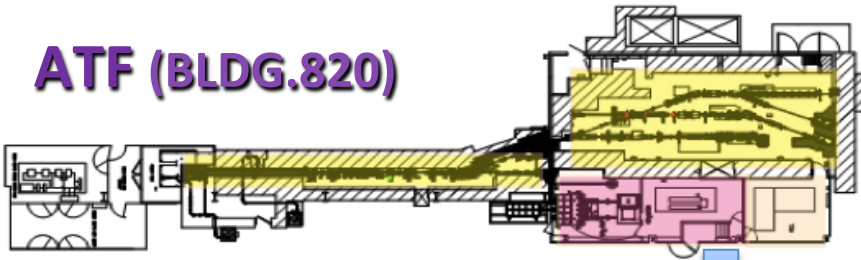
Accelerator Test Facility



ATF II upgrade funded by DOE HE
under Accelerator Stewardship program

MAJOR FACILITY UPGRADE

ATF (BLDG.820)

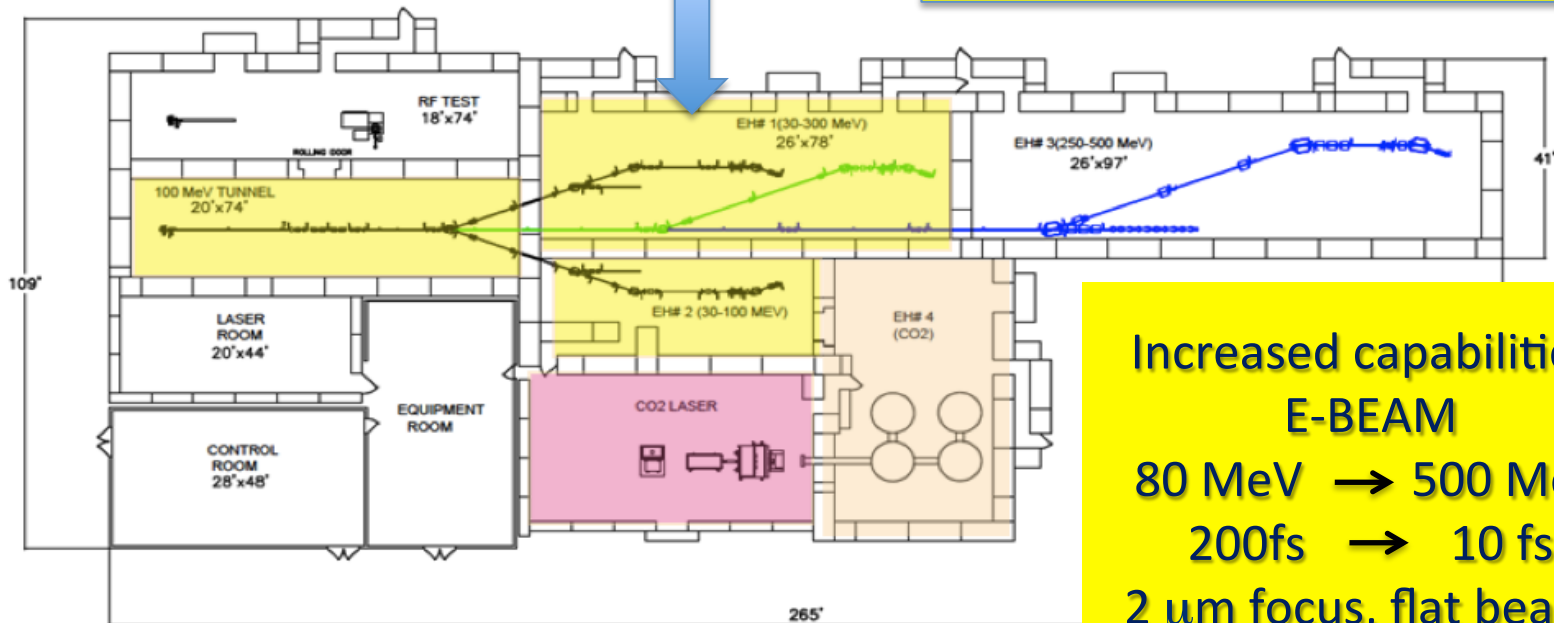


Towards higher productivity:

Exp. Halls:
x5

Shielded
area:
x7

Total
floor:
x3



ATF II (BLDG.912)

Increased capabilities:

E-BEAM

80 MeV → 500 MeV

200fs → 10 fs

2 μm focus, flat beams

LASER

1 TW → 100 TW

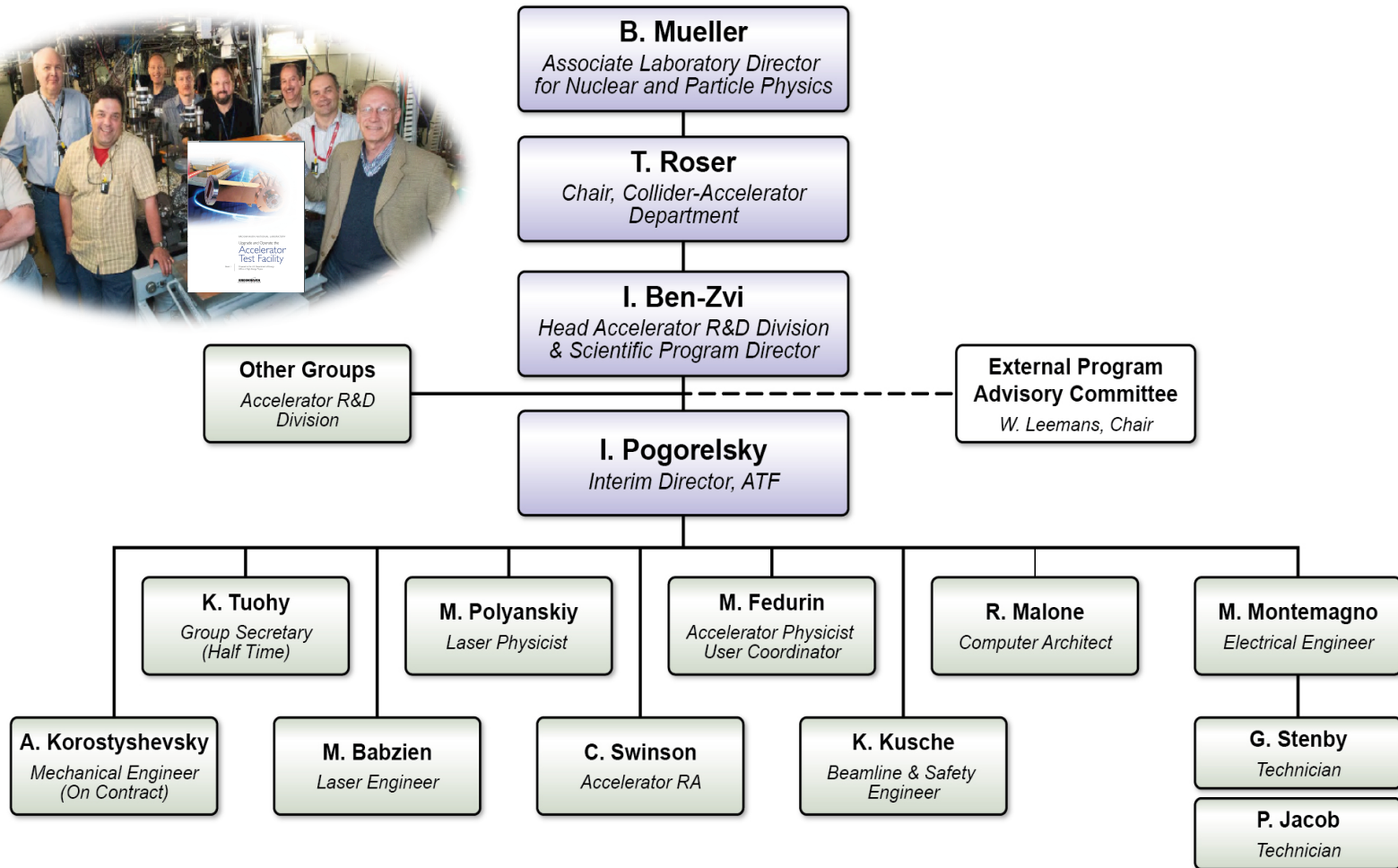
ATF vision

Providing users with research opportunities :

- not available elsewhere,
- at the cutting edge of strong-field physics and advanced accelerator science,
- with diverse coverage of Office of Science missions in Accelerator R&D and Stewardship.

Thank you for your attention

ATF organizational chart



ATF is a proposal driven, Program Committee reviewed user facility.

J A S O N D | J F M A M J J A S O N D | J F M A M J J A S O N D | J F M A M J J A S

14

15

16

17

Stage 1 Detailed facility design & RSC review

Equipment Move from SDL, MIT & component purchases

IHEP collaboration supporting ATF2 under US / China collaboration agreements

ATF2 controls development

100 TW CO2 laser component contracts, PFN and HP vessels

Conventional Facility Design

Construction of Shielding walls

Assy 912 CO2 laser lab

Survey

Integrate PFN & HP Vessel begin syst. tests in 912

DOE Review

ATF2 Stage 2

Install utilities for stage 1

controls & sub system integration

Fab.. CO2 tspt Lns

Instal.CO2 tspt Lns

CO2,1-40+ TW System

Procure & install Laser Lab

Solid state Laser Lab

Assy. Gun, Linac & beam lines

First experiments set up at linac or BL 1 accel. physics research at ATF2

Install UED gun & exp. laser Lns

Assy BM Ln 1

migration 820 to 912

Develop UED Controls UED ops stay at SDL

Install UED & New Controls

Run utilities to componts

Gun and Linac commissioning

Install utilities for stage 2

Assy BM Ln 2

Decommission 820

UED 912 Commis

Continuous UED operations in 912

Beam line 1 commissioning

Beam Line 2 commissioning

Transfer ATF Ops. to 912

BROOKHAVEN
NATIONAL LABORATORY
a passion for discovery

OFFICE OF
ENERGY
SCIENCE

QT3

QT4

QT5

QT6

QT7

QT8

QT9

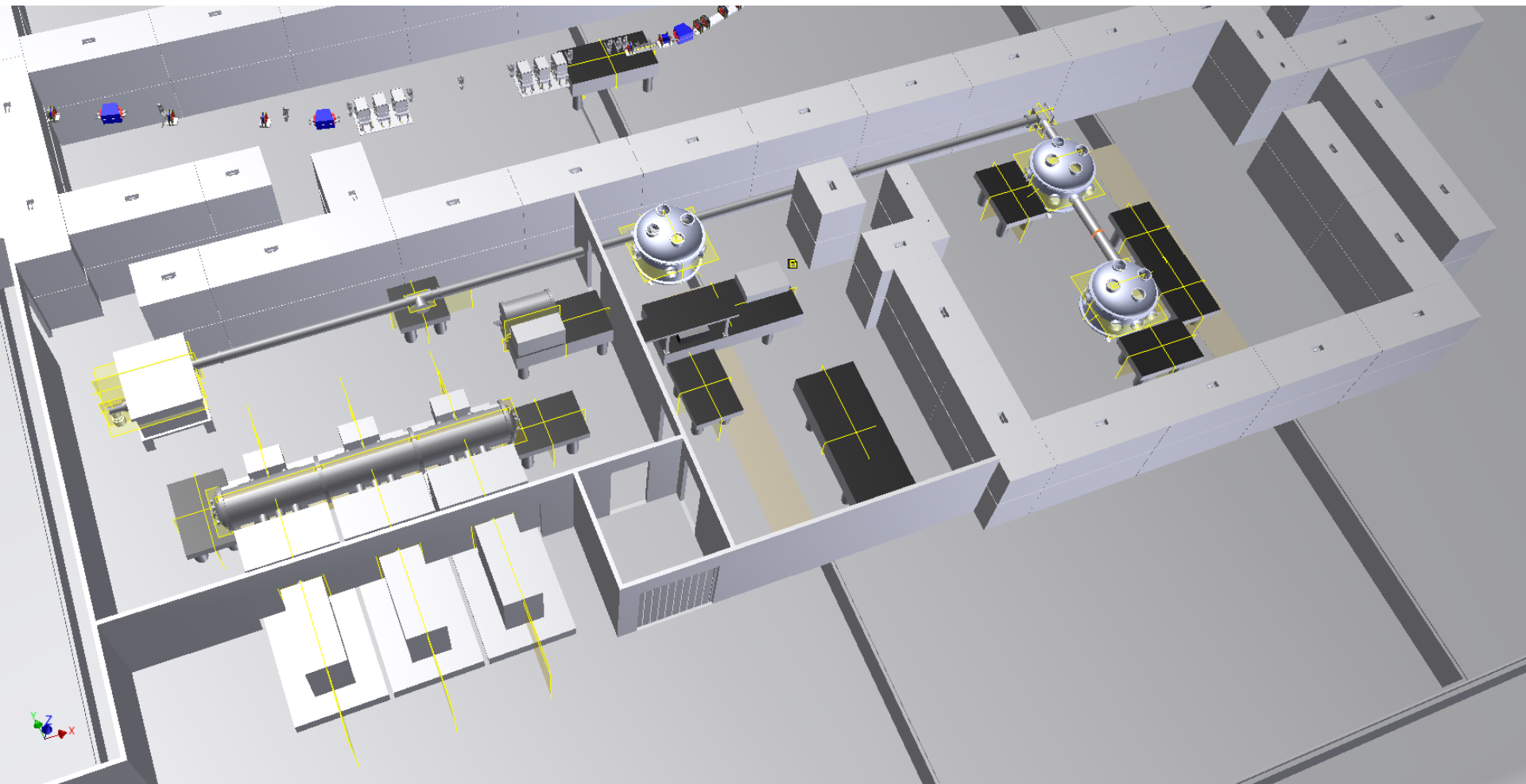
QT10

QT11

QT12

QT13

Floor plan of 100 TW CO₂ laser and Ion Acceleration Hall





• Diversified scope of research

- ❑ The S-band photocathode electron gun 1995, and beam brightness records
- ❑ 3.5 MeV acceleration of electrons using the Inverse Cerenkov effect 1995
- ❑ Forward Directed Smith-Purcell Radiation from Relativistic Electrons 1995
- ❑ Demonstration of Emittance Compensation through the Measurement of the Slice Emittance 1996
- ❑ 1 MeV Inverse Free-Electron Laser acceleration experiment 1996
- ❑ Experimental Observation of Femtosecond Electron Beam Micro-bunching by Inverse Free-Electron-Laser Acceleration 1998
- ❑ Experimental observation of ballistic bunching of relativistic electrons 1996
- ❑ Self Amplified Spontaneous Emission (SASE) in the visible 1998
- ❑ Precision tomographic measurement of the beam density in phase-space 1998
- ❑ Experimental Observation of Suppression of Coherent-Synchrotron-Radiation-Induced Beam-Energy Spread with Shielding Plates 2012
- ❑ Study of wall roughness effects 2012
- ❑ Demonstration of High-Gain Harmonic-Generation FEL 2000

• Notable achievements

- ❑ Staged laser accelerator (IFEL) 2000
- ❑ A number of records in inverse Compton generation of X-rays 1998-2006-2013
- ❑ Demonstration of phasing between longitudinal and transverse components in plasma wakefields 2003
- ❑ First staged monoenergetic laser electron acceleration (STELLA) 2004
- ❑ Demonstration of particle acceleration by stimulated emission of radiation 2006
- ❑ In-depth studies of PWA with multiple electron bunches 2008-present
- ❑ Monoenergetic laser-driven proton source by shock wave acceleration 2010
- ❑ Demonstration of beam statistical noise reduced below the shot-noise limit 2011
- ❑ Phase contrast imaging of bio samples by single-shot picosecond Compton 2011
- ❑ Study of shielding effects of coherent synchrotron radiation 2011
- ❑ First experimental observation of the Current Filamentation Instability 2012

Color code: HEP BES NP Biomedical